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The NREL Outdoor Accelerated-Weathering Tracking System Photovoltaic Module Exposure Results

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ABSTRACT

Status results are presented for the Outdoor Accelerated-Weathering Tracking System (OATS) first study on photovoltaic (PV) modules. Studies began in November 1997 on pairs of commercially available crystalline silicon and amorphous silicon (a-Si) PV modules kept at constant resistive load. The modules do show weathering, but there were no module failures. Through February 2000, the PV modules under OATS reflector conditions received 1286 MJ/m^2 of total ultraviolet (TUV) exposure, and the modules under the covered reflectors received 809 MJ/m^2.

1. General Introduction

The OATS system [1] provides accelerated stress testing, and this study's purpose is to assess PV module durability to ultraviolet (UV) radiation and outdoor exposure, focusing on degradation of module encapsulants and other polymer components, the PV device structures, and general module components. Test protocol was based on existing standards [2,3]. Pairs of commercially available crystalline silicon and a-Si PV modules (Table 1) were deployed in the two OATS test planes. One test plane has its reflectors covered so the irradiance is nominally equal to that of a two-axis tracker, and the second test plane experiences sunlight concentration by four flat-plate aluminum reflectors at 45° to the sun (3X concentration theoretical maximum). Each module is at a resistive load calculated to provide one-sun maximum power-point operation. In-situ monitoring is back-of-module temperature, load current and voltage, and once a day, the module short-circuit current and open-circuit voltage are measured when total-irradiance tracking is near 1000 W/m^2. This OATS study will continue to 2000 MJ/m^2 TUV exposure or until failure, defined as module power having decreased to 25% of its initial value. The TUV exposure level is defined as the UV irradiance integrated below 400 nm. At varied intervals, the PV modules are removed from OATS for visual inspection and solar-simulator performance measurements. When modules pass the rated power criteria, they are returned to OATS; otherwise, they will undergo failure analysis.

2. Results

Status results and comments follow. There were no module failures and visual inspections show minor anomalies. The reported exposure levels include a 1.26 multiplier to account for the TUV radiometer (TUVR) instrument spectral response ending at 385 nm. Measurements at NREL's Solar Radiation Research Laboratory were used to establish that multiplier [4].

The current-voltage (I-V) power performance data are compared to the 3/97 baseline (Table 2), not the 11/97 values. From the table, one can see that module #10 at OATS one-sun exposure was at 96.3% power in 2/00 after 809 MJ/m^2 TUV exposure, and the same model PV module #2 at concentration exposure was at 94.5% in 2/00 after 1286 MJ/m^2. Only the a-Si modules showed any substantial change, which is primarily attributed to the Staebler-Wronski effect.

The OATS cumulative TUV exposure through 2/00 for the PV modules under reflector conditions was 1286 MJ/m^2, and for modules in the test plane with the reflectors covered, it was 809 MJ/m^2.

This initial PV module study is ongoing. When failures or substantial visual anomalies are noted, they will be compared to results of other exposure methods. Further, for this ongoing PV module exposure study, the data, results, and the OATS system description will be documented in a detailed NREL report planned for Fall 2000.

TABLE 1. OATS Test Photovoltaic Module Descriptions

Manufacturer	**Module Models**	**Technology**
Siemens Solar Industries	M10 & Pro 1JF	crystalline silicon
Solarex Corp.	MSX10 & MSX20	crystalline silicon
United Solar Systems Corp.	UniSolar 1206 & 1212	Dual-junction amorphous silicon

TABLE 2. Photovoltaic Module Relative Power [(a)] after OATS Exposure[(b)]

OATS TUV Exposure[(b)] Levels in MJ/m^2 (Date) for Modules #2 - #7 and Modules #10 - #15							
#2 - #7	0 (11/97)	54 (1/98)	165 (3/98)	260 (5/98)	392 (7/98)	1100 (9/99)	1286 (2/00)
#10 - #15	0 (11/97)	54 (2/98)	158 (5/98)	240 (8/98)	-----	703 (10/99)	809 (2/00)
Module Model - #	**Relative Power[(a)] (% @ standard reporting conditions)**						
M10 #2	98.2	96.3	97.6	98.0	95.8	95.6	94.5
M10 #10	98.2	98.3	98.9	97.5	-----	96.5	96.3
Pro1JF #3	97.2	95.9	96.2	97.0	95.7	94.6	93.5
Pro1JF #11	97.3	96.1	94.9	94.8	-----	94.0	93.3
MSX10 #4	99.2	98.2	98.5	98.7	97.6	95.5	95.6
MSX10 #12	98.5	97.7	97.2	97.1	-----	95.5	85.2
MSX20 #5	99.2	97.3	98.3	98.8	97.1	96.8	95.2
MSX20 #13	98.7	98.2	98.1	99.8	-----	96.5	96.9
1206 #6	85.6	77.8	71.7	71.0	72.8	69.8	64.5
1206 #14	84.3	67.1	64.7	65.7	-----	67.4	64.4
1212 #7	86.1	80.0	74.2	74.6	74.3	72.3	66.5
1212 #15	89.2	71.4	68.2	68.9	-----	72.2	67.8

(a) Module power % is relative to 3/97 measurement.
(b) All modules were exposed to 1-sun conditions outdoors, about 30 days during 3/97 to 11/97.
Modules #2 - #7 @ OATS reflector conditions.
Modules #10 - #15 @ OATS covered-reflector conditions.

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4. References

[1] T. S. Basso, "The NREL Outdoor Accelerated-Weathering Tracking System and Photovoltaic Module Exposure Results," *NCPV Photovoltaics Program Review Proceedings of the 15th Conference*, American Institute of Physics AIP Conference Proceedings 462 (1998) 643 - 648.

[2] *ASTM E 1596 Standard Test Methods for Solar Radiation Weathering of PV Modules*, American Society for Testing and Materials, West Conshohocken, PA (1994).

[3] *ASTM E 1799 Standard Practice for Visual Inspections of Photovoltaic Modules*, American Society for Testing and Materials, West Conshohocken, PA (1996).

[4] D. Myers, NREL interoffice memo, Computing UV integral dose from TUVR data, NREL, Golden, CO (February 4, 1997).